RECORD OF DECISION

REMEDIAL ACTION APPROACH

For

COLUMBIA SLOUGH SEDIMENT
PORTLAND, OREGON

Prepared By

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY
Northwest Region Office

JULY 2005

TABLE OF CONTENTS

1. INTRODUCTION

1.1 INTRODUCTION

This document presents the selected remedial approach for contaminated sediment in the Columbia Slough. The Columbia Slough is located south and parallel to the Columbia River and consists of approximately 31 miles of water way extending from Fairview Lake on the east side to the Willamette River on the west. This remedial approach was developed consistent with Oregon Revised Statutes (ORS) 465.200 et. seq. and Oregon Administrative Rules (OAR) Chapter 340, Division 122, Sections 0010 through 0115. It is intended to lay the foundation for a coordinated, watershed-based approach and provide the framework for future specific remedial action decisions addressing sediment contamination in the Columbia Slough. Specific remedial actions required for discrete sources contributing to Slough sediment contamination will be selected consistent with this remedial approach and in accordance with the applicable sections of ORS Chapter 465 and OAR Chapter 340 Division 122.

The selected remedial approach is based on the administrative record for this site. A copy of the Administrative Record Index is attached as Appendix A. This report summarizes the more detailed information contained in the Feasibility Study and multiple investigation reports completed under Consent Order No. ECSR-NWR-93-09 between the City of Portland and the Oregon Department of Environmental Quality (DEQ).

1.2 SCOPE AND ROLE OF THE SELECTED REMEDIAL APPROACH

The selected remedial approach addresses contaminated sediment in the Columbia Slough. Sediment within the Columbia Slough contains a range of contaminants associated with urban activities (*e.g.*, petroleum, polycyclic aromatic hydrocarbons, PCBs, phthalates, and metals) as well as legacy contaminants associated with historical agricultural practices. In addition to widespread sources of pollution, Slough sediments have been contaminated by direct discharges, surface run-off, and groundwater contamination from industrial facilities. The selected remedial approach consists of the following elements:

- Identify current and historical localized sources of contamination in Slough sediments and potential sources contributing, or that have contributed, to sediment contamination (*e.g.*, upland

sources), to the extent practical.

- Provide a framework for integrating upland source control activities with in-water Slough remedial actions. Remedial actions at upland facilities will be selected in accordance with Oregon Environmental cleanup regulations, giving consideration to this overall Columbia Slough remedial framework. This will include reducing releases of contamination from discrete sources to levels protective of human health and the environment.
- Remediate elevated levels of sediment contamination to Slough "baseline" levels.
- Implement measures in upland areas within the Slough watershed to reduce widespread sources of contamination and prevent future discharges from potential sources.
- Conduct long-term monitoring and evaluation to assess the effectiveness of remedial measures and modify the approach as warranted.
- Complete evaluation of the adequacy of remedial measures implemented, and ultimately on the achievement of protective cleanup levels, for segments of the Slough defined by water flow characteristics.

2. SITE HISTORY AND DESCRIPTION

2.1 SITE LOCATION AND LAND USE

The Columbia Slough Watershed drains approximately 32,700 acres of land (see Figure 1). Portland's city limits end at approximately NE 185th Avenue on the east, but the watershed includes Fairview Lake and Fairview Creek, and portions of Troutdale, Fairview, Gresham, Maywood Park, Wood Village, and unincorporated Multnomah County.

The Watershed historically contained a vast system of side channels, streams, ponds, lakes, and wetlands that covered the floodplain of the Columbia River between the mouths of the Willamette and Sandy Rivers. High water seasonally inundated the floodplain, cutting new channels and depositing sediment. Native Americans used these waterways and the uplands for fishing, hunting, and gathering food. Fishing continues in this area.

Over the years, the Watershed and waterway have been drastically altered. Beginning in 1918, levees were built and wetlands were drained and filled to provide flood protection and allow for development. The waterway was channelized, and dozens of streams were diverted from natural channels to underground pipes. Today, the Columbia Slough comprises a 19-mile main channel that parallels the Columbia River, as well as approximately 12 additional miles of secondary waterways. Other remaining major surface water features include Fairview Creek, Fairview Lake, and Smith and Bybee Lakes. Floodplain development has resulted in an extensively managed surface water system that includes levees, pumps, and other water control structures. The levee system has greatly changed the historic floodplain and reduced the area available to floodwaters.

The Columbia Slough Watershed now includes virtually every type of land use: residential neighborhoods, commercial and industrial development, agriculture, Portland International Airport (PDX), interstate highways, railroad corridors, 54 schools, and large open spaces. Much of Portland's industrial and commercial land is located within the Watershed. In addition to industrial development in the area north of Columbia Boulevard and the Rivergate area, land is preserved for industrial uses in the Columbia South Shore area between NE 82nd and NE 185th Avenues north of Sandy Boulevard.

2.2 PHYSICAL SETTING

The Slough is divided into three sections, based on hydraulic characteristics:

- The **Upper Slough** starts at the mouth of Fairview Lake on the east and flows west to the mid-dike levee at NE 142nd Avenue. It receives water from Fairview Lake, Fairview Creek, Wilkes Creek, stormwater outfalls, natural springs, groundwater, and overland flow.

- The **Middle Slough** extends from the mid-dike levee near NE 142nd Avenue to the Pen 2 levee near NE 18th Avenue. It includes a substantial southern arm complex of sloughs and lakes, including Prison Pond, Mays Lake, Johnson Lake, Whitaker Slough, Whitaker Ponds, and Buffalo Slough. The Middle Slough receives water from the Upper Slough, stormwater outfalls, natural springs, overland flow, and groundwater. Pumps are used to move water from the Upper and Middle Slough to the Columbia River or the Lower Slough.

- The **Lower Slough** starts at the Pen 2 levee, near NE 18th Avenue, and extends approximately 8.5 miles to the Willamette River. The lowlands of the Lower Slough Watershed are subject to flooding because they are not protected by levees. Water flow and levels in the Lower Slough are affected primarily by the Columbia River and Willamette River and the ocean tides, as well as by pumping. During high tide, the Columbia and Willamette Rivers create a backwater effect that complicates flow patterns.

2.3 SOURCES OF CONTAMINATION

Over time, extensive alteration of the Slough's watershed, due to industrial and residential development, has had a deleterious effect on the environmental quality of the Watershed. As development occurs, the natural topography, hydrology, and vegetation are altered and impervious surfaces such as streets, parking lots, and buildings are placed over much of the land. As a result of urbanization, industrial releases, alteration of water flows, and runoff from agricultural land, the Columbia Slough has polluted water, sediments and fish.

DEQ placed the Columbia Slough on the State's 303(d) list in 1994. The 303(d) list identifies water bodies that are "water quality limited" because they do not meet water quality standards for certain parameters. The Slough is listed as water quality-limited for bacteria, phosphorus, dissolved oxygen, chlorophyll a, toxics (dichlorodiphenyltrichloroethane/dichlorodiphenyldichloroethylene (DDT/DDE), dieldrin, dioxins, PCBs, and lead), pH and temperature. The Oregon Health Division (OHD) issued a health advisory addressing consumption of fish from the Slough based on the detection of PCB and pesticides in fish collected from the Slough in the vicinity of the St. John's Landfill.

3. RESULTS OF INVESTIGATION(S)

3.1 NATURE AND EXTENT OF CONTAMINATION

Multiple investigations of the Columbia Slough sediment have been conducted by the City of Portland, the U.S. Army Corp of Engineers (COE), DEQ, and others from approximately 1989 to the present. A Screening Level Risk Assessment (SLRA) completed by the City of Portland in 1994 involved the collection of 300 sediment samples, 36 fish tissue samples, and a compilation of existing sediment data. This investigation generally indicated that Slough sediments contain a broad array of contaminants at relatively low levels throughout the entire 31 miles of waterway. Fish tissue was found to contain PCBs, pesticides, and lead at levels that may pose an unacceptable risk to people and wildlife that eat the fish.

In addition to the SLRA, more focused investigations have been conducted in particular sections of the Slough both as part of the City's broad investigation and as a part of more localized investigations of particular contaminated sites. Sites identified by DEQ and their status in the cleanup program, including whether sediment sampling has been completed as of June 2005 are identified in Table 2. The more significant investigations conducted by the City are summarized below.

3.1.1 Buffalo Slough

Analytical results for several of the SLRA samples collected in the Buffalo Slough showed elevated concentrations of contaminants. In 1995, a focused investigation of the sediment in the Buffalo Slough was initiated. This investigation included the collection of 59 surface sediment samples, 18 core samples, 13 pore water samples, 5 fish tissue samples, and 7 sediment toxicity bioassays. A risk assessment completed using this data indicated a potential unacceptable risk to humans and wildlife who ingest fish from this portion of the Slough. A Feasibility Study was prepared; however, questions were raised about the feasibility of implementing various remedial options without fully addressing diffuse sources of contamination.

3.1.2 Peninsula Drainage Canal

In 1997/98 a survey of fish consumption was completed for the Peninsula Drainage Canal (PDC) and risks were calculated based on data for fish tissue collected in this area. Calculated risk fell below acceptable risk levels as defined in OAR 340-122-115 and DEQ provided a conditional No Further Action determination for this segment of the Slough. The conditions indicate that

monitoring of the Slough must include this section as sediment concentrations, while consistent with baseline levels established for the Slough, remain elevated above risk-based screening concentrations.

3.1.3 Wapato Wetlands

In 1997, a focused investigation was conducted for the Wapato Wetlands, located in the Lower Slough. The investigation included the collection of 28 surface and core sediment samples and Wapato plant samples. The investigation found limited contamination in the vicinity of a City outfall but it was determined that the contaminants were not present in a form that would make them toxic (not bioavailable) and did not pose an unacceptable risk to aquatic life, wildlife, and human health. DEQ provided a No Further Action determination for this area.

3.1.4 Marx-Whitaker Sub-basin

The Marx-Whitaker Sub-basin is located between N.E. 122nd and 128th Avenues at the eastern end of the Whitaker Slough. Two investigations were conducted in this area subsequent to the SLRA. In 1997, surface and core sediment samples were collected from 11 locations and bioassays performed on 8 samples to determine the nature and extent of contamination. Elevated concentrations of pesticides that posed an unacceptable risk to aquatic organisms living in the sediment were identified. A follow-up investigation, conducted in 1998 determined that the primary source of elevated pesticides in this area was erosion and runoff of soil from agricultural properties that were connected to the Slough via storm drain lines.

3.1.5 Other Investigations

The COE and Multnomah County Drainage District (MCDD) have also conducted sampling in the Columbia Slough.

In 1998, the COE collected 15 sediment samples in the lower Slough to evaluate the potential for conducting dredging to improve ecological habitat in the Slough. Analytical results indicated that sediment in this section of the Slough was too contaminated to feasibly conduct the work, which would involve in-water placement of dredged material. A similar study completed in 1999 for the Middle and Upper Slough revealed lower levels of contamination and the channel modifications (creation of “meandering streams”) were implemented.

MCDD periodically conducts sediment sampling to evaluate necessary disposal protocols for material that must be dredged to maintain flow around pump stations and in tributary ditches to the Slough.

3.2 RISK ASSESSEMENT

The standards for a protective cleanup are defined in the Oregon Revised Statute (ORS) and Oregon Administrative Rule (OAR). ORS 465.315 states in part:

> **Standards for degree of cleanup required; Hazard Index; risk protocol; hot spots of contamination; exemption.** (1)(a) Any removal or remedial action performed under the provisions of ORS 465.200 to 465.510 and 465.900 shall attain a degree of cleanup of the hazardous substance and control of further release of the hazardous substance that assures protection of present and future public health, safety and welfare and of the environment.
>
> (b) The Director of the Department of Environmental Quality shall select or approve remedial actions that are protective of human health and the environment. The protectiveness of a remedial action shall be determined based on application of both of the following:
>
> (A) The acceptable risk level for exposures. For protection of humans, the acceptable risk level for exposure to individual carcinogens shall be a lifetime excess cancer risk of one per one million people exposed, and the acceptable risk level for exposure to noncarcinogens shall be the exposure that results in a Hazard Index number equal to or less than one. "Hazard Index number" means a number equal to the sum of the noncarcinogenic risks (hazard quotient) attributable to systemic toxicants with similar toxic endpoints. For protection of ecological receptors, if a release of hazardous substances causes or is reasonably likely to cause significant adverse impacts to the health or viability of a species listed as threatened or endangered pursuant to 16 U.S.C. 1531 et seq. or ORS 496.172, or a population of plants or animals in the locality of the facility, the acceptable risk level shall be the point before such significant adverse impacts occur.
>
> (B) A risk assessment undertaken in accordance with the risk protocol established by the Environmental Quality Commission in accordance with subsection (2)(a) of this section.

OAR 340-122-0115 provides additional definition of protectiveness:

> (1) "Acceptable risk level" with respect to the toxicity of hazardous substances has the meaning set forth in ORS 465.315 (1)(b)(A) and (B) and is comprised of the acceptable risk level definitions provided for carcinogenic exposures, noncarcinogenic exposures, and ecological receptors in sections (2) through (6) of this rule.
>
> (2) "Acceptable risk level for human exposure to individual carcinogens" means:
>
> (a) For deterministic risk assessments, a lifetime excess cancer risk of less than or equal to one per one million for an individual at an upper-bound exposure; or
>
> (b) For probabilistic risk assessments, a lifetime excess cancer risk for each carcinogen of less than or equal to one per one million at the 90th percentile, and less than or equal to one per one hundred thousand at the 95th percentile, each based upon the same distribution of lifetime excess cancer risks for an exposed individual.
>
> (3) "Acceptable risk level for human exposure to multiple carcinogens" means the acceptable risk level for human exposure to individual carcinogens and:
>
> (a) For deterministic risk assessments, a cumulative lifetime excess cancer risk for multiple carcinogens and multiple exposure pathways of less than or equal to one per one hundred thousand at an upper-bound exposure; or

(b) For probabilistic risk assessments, a cumulative lifetime excess cancer risk for multiple carcinogens and multiple exposure pathways of less than or equal to one per one hundred thousand at the 90th percentile and less than or equal to one per ten thousand at the 95th percentile, each based upon the same distribution of cumulative lifetime excess cancer risks for an exposed individual.

(4) "Acceptable risk level for human exposure to noncarcinogens" means:

(a) For deterministic risk assessments, a hazard index less than or equal to one for an individual at an upper-bound exposure; or

(b) For probabilistic risk assessments, a hazard index less than or equal to one at the 90th percentile, and less than or equal to ten at the 95th percentile, each based upon the same distribution of hazard index numbers for an exposed individual.

(5) "Acceptable risk level for individual ecological receptors" applies only to species listed as threatened or endangered pursuant to 16 USC 1531 et seq. or ORS 465.172, and means:

(a) For deterministic risk assessments, a toxicity index less than or equal to one for an individual ecological receptor at an upper-bound exposure, where the toxicity index is the sum of the toxicity quotients attributable to systemic toxicants with similar endpoints for similarly-responding species and the toxicity quotient is the ratio of the exposure point value to the ecological benchmark value; or

(b) For probabilistic risk assessments, a toxicity index less than or equal to one at the 90th percentile and less than or equal to 10 at the 95th percentile, each based on the same distribution of toxicity index numbers for an exposed individual ecological receptor; or

(c) The probability of important changes in such factors as growth, survival, fecundity, or reproduction related to the health and viability of an individual ecological receptor that are reasonably likely to occur as a consequence of exposure to hazardous substances is de minimis.

(6) "Acceptable risk level for populations of ecological receptors" means a 10 percent chance, or less, that no more than 20 percent of the total local population will be exposed to an exposure point value greater than the ecological benchmark value for each contaminant of concern and no other observed significant adverse effects on the health or viability of the local population.

OAR 340-122-0084 describes the requirements for risk assessments for determining concentrations corresponding to acceptable risk levels. A quantitative risk assessment for the Columbia Slough sediments has not been completed. However, a screening level risk assessment has been completed and is documented in the SLRA report (Parametrix 1995) and more focused evaluations have been completed for the Buffalo Slough (Parametrix 1997), Peninsula Drainage Canal (Portland 1998), and Marx-Whitaker Sub-Basin (Ecology and Environment 1998).

3.2.1 Baseline Evaluation

Because the Columbia Slough is located in an urban area and has been receiving stormwater runoff from a wide variety of land uses throughout its 31 miles of interconnected waterways, virtually every sediment sample evaluated as part of the 1994 screening level risk assessment contained concentrations of one or more contaminants that exceeded conservative risk-based screening levels, except, as discussed below, for levels based on human exposure through direct contact. This type of area-wide contamination makes it difficult to establish remedial action goals in sediment for identified discrete sources using the typical risk-based approach. Particularly in environments where contaminants tend to move via erosion and water flow, it is

generally not practical to remediate localized areas to risk-based concentrations when surrounding areas are contaminated at higher concentrations and have a high likelihood of recontaminating the remediated area. To address this issue in the Columbia Slough, the existing database was analyzed to determine "baseline" concentrations of frequently detected contaminants of concern. The baseline or ambient concentration for a particular contaminant reflects the upper end of the range of concentrations of that contaminant that could be expected to be pervasive throughout the Slough sediment. This concentration range should not include concentrations associated with discrete source areas which would cause the sediment concentrations to be indicative of a different population of data. The process for coming up with the baseline concentrations relied on graphical evaluation of concentration data using methods developed by the U.S. Geological Survey. The baseline values are provided in Table 1 and documentation of their derivation is provided in "Columbia Slough Baseline Concentrations Documentation of Methodology" (DEQ 2002).

3.2.2 Conceptual Site Model

A conceptual site model identifies contaminated media at a site and exposure pathways through which the contaminants could reach receptors of concern. Human exposure to contaminants in the Slough can occur through direct contact (*e.g.*, wading or swimming, incidental ingestion of suspended sediments) or indirect contact via ingestion of fish that have accumulated contaminants in their tissue. A conceptual site model is provided in the Columbia Slough Feasibility Study, Figure 2-1.

Potential exposures of concern for ecological receptors in the Slough include: ingestion of contaminated fish by birds or mammals; uptake by fish of contaminants in sediment, water column and food sources; and uptake of contaminants by sediment dwelling organisms.

3.2.3 Human Health Contaminants of Concern

Because of the limited contact people have with contaminated sediment in the Slough and the generally low concentrations of contaminants detected in Slough sediment relative to levels of concern for direct contact, the direct contact exposure pathway for humans is not considered to be of concern. A comparison of baseline values to risk-based screening levels (called preliminary remediation goals or PRGs) considering a residential exposure scenario indicates that baseline values for benzo(a)pyrene and chromium slightly exceed the residential PRGs. Considering that the time frames and frequencies for exposure to Slough sediment would be significantly lower than the values used to determine residential soil PRGs, these concentrations do not pose an unacceptable risk for direct contact. The only other compound that had a baseline value that was higher than the residential PRG was arsenic for which the baseline value is consistent with likely natural background concentrations. The baseline value for arsenic is 8.4 ppm and the accepted freshwater sediment background concentration for arsenic is 7.9 ppm. Consequently, the only exposure route of concern for humans is ingestion of fish that have accumulated contaminants from the sediments, water column, or food sources.

To determine which contaminants present an unacceptable risk for this pathway, the fish tissue data obtained during the SLRA were compared to Acceptable Tissue Levels (ATLs) for fish. The ATLs were derived using the acceptable risk levels established in Oregon cleanup regulations and assuming fish consumption rates determined by a field angler survey in the Columbia Slough. The following contaminants were found in fish tissue at levels that exceed the ATLs for human ingestion of fish: arsenic, copper, lead, mercury, zinc, PCB Aroclor 1254, PCB Aroclor 1260, PCB Aroclor 1248, DDT, DDD, DDE, aldrin, chlordane, heptachlor, dieldren, chrysene, and indeno(1,2,3-cd)pyrene.

3.2.4 Ecological Contaminants of Concern

A wide range of contaminants including: semi-volatiles, pesticides, metals, and PCBs were found to be present in Slough sediment at concentrations of concern for one or more pathways based on comparison of concentrations detected to conservative screening levels associated with aquatic toxicity. Many of the contaminants identified as a concern for human health via bioaccumulation also exceeded conservative screening levels based on impacts to birds and mammals. Volatile contaminants were generally not detected at concentrations of concern in sediment. However, because volatile compounds typically have high solubilities and tend to be relatively mobile and easily degradable, their detection in sediments, even in low concentrations may indicate an on-going release, either through surface water runoff (including spills or illegal dumping) or groundwater migration, that warrants further investigation. Essentially, every sediment sample collected from the Slough in the SLRA contained one or more contaminants at elevated concentrations; consequently, contaminants of concern include phthalates, PAHs, PCBs pesticides, and metals.

3.3 HOT SPOT CRITERIA

Characterization of a site also includes whether a “hot spot” is present.

OAR 340-122-115(32) defines hot spot of contamination for groundwater and surface water and for other media such as sediments:

> (a) For groundwater or surface water, hazardous substances having a significant adverse effect on beneficial uses of water or waters to which the hazardous substances would be reasonably likely to migrate and for which treatment is reasonably likely to restore or protect such beneficial uses within a reasonable time, as determined in the feasibility study; and
>
> (b) For media other than groundwater or surface water, (*e.g.*, contaminated soil, debris, sediments, and sludges; drummed wastes; "pools" of dense, non-aqueous phase liquids submerged beneath groundwater or in fractured bedrock; and non-aqueous phase liquids floating on groundwater), if hazardous substances present a risk to human health or the environment exceeding the acceptable risk level, the extent to which the hazardous substances:
>
> (A) Are present in concentrations exceeding risk-based concentrations corresponding to:
>
> (i) 100 times the acceptable risk level for human exposure to each individual carcinogen;

(ii) 10 times the acceptable risk level for human exposure to each individual noncarcinogen; or

(iii) 10 times the acceptable risk level for exposure of individual ecological receptors or populations of ecological receptors to each individual hazardous substance.

(B) Are reasonably likely to migrate to such an extent that the conditions specified in subsection (a) or paragraphs (b)(A) or (b)(C) would be created; or

(C) Are not reliably containable, as determined in the feasibility study.

3.3.1 Surface Water Beneficial Use Determination

OAR 3401-122-115(9) defines beneficial uses of water as:

> any current or reasonable likely future beneficial use of groundwater or surface water by humans or ecological receptors.

Beneficial uses for surface waters of the Columbia Slough include recreation (*e.g.*, fishing, swimming) wildlife habitat and food source, and salmonid rearing (lower Slough). While the purpose of the selected remedial approach is to clean up sediments, beneficial uses of surface water are pertinent in that sediment contamination may be considered a hot spot if associated contamination migrates to surface water and cause a significant adverse impact to the surface water beneficial uses. A relationship between sediment concentrations and fish tissue concentrations can be estimated using biota sediment accumulation factors (BSAFs). This type of evaluation indicates that sediment concentrations in the Slough are likely resulting in unacceptable concentrations of contaminants in fish tissue considering potential impacts to humans and wildlife that consume the fish.

3.3.2 Sediment Hot Spots

While baseline concentrations for a wide range of contaminants present in the Columbia Slough sediment exceeds risk based concentrations, the exceedances tend to be relatively small. Sediment hot spots are likely only present in those discrete areas where baseline concentrations are exceeded. Because of the large area covered by this evaluation and the variety of potential sources of contamination, specific sediment hot spots have not been identified; however, the future site-specific identification of sediment hot spots and the evaluation of the feasibility of their treatment or removal have been incorporated into the selected remedial approach described in Section 7.

4. PEER REVIEW SUMMARY

Technical documents produced during the investigation of the Columbia Slough Sediment site have been reviewed by a technical team at DEQ. The team consists of the project manager, site assessment specialists, water quality specialists, hazardous waste experts, a toxicologist, and various project managers providing peer review. The team unanimously supports the selected remedial approach.

5. DESCRIPTION OF REMEDIAL ACTION OPTIONS

5.1 REMEDIAL ACTION OBJECTIVES

As indicated above, contamination is pervasive throughout the Columbia Slough sediments. Much of the contamination is most likely from discharges typical of an urban environment that occur throughout the Slough Watershed. In addition, there are several contaminated sites and facilities that historically discharged to the Slough that have added and may continue to add to the mix of contamination found in the sediments. Because the methods for addressing these two types of sources is necessarily different, an important step in the development of an overall remedial approach for the Slough was to attempt to differentiate contamination associated with widespread sources from contamination associated with specific releases. The baseline levels described in Section 3.2.1, represent the best estimate of sediment concentrations resulting from historic widespread pervasive contamination inputs to the Slough. Contaminant concentrations that exceed these levels, therefore, are assumed to be indicative of an additional contaminant source.

5.1.1 Tier 1 Remedial Action Objective

For discrete sources of contamination to the Slough, cleaning up associated impacted sediment to risk-based concentrations may not be practical due to the presence of contaminants in surrounding sediments at baseline levels that exceed risk-based levels. In these cases, it is appropriate to establish a practical remedial action objective for active cleanup to the baseline concentrations. This is considered Tier 1 cleanup because it can be readily implemented in conjunction with site-specific investigations and remedial evaluations. The applicability of the Tier 1 RAO will be evaluated on a site-by-site basis.

5.1.2 Tier 2 Remedial Action Objectives

The ultimate objective of this remedial approach proposed for the Columbia Slough sediments is to reduce contaminant concentrations to protective levels considering all potential exposure scenarios. Risk-based screening levels have been derived for the Slough considering site specific fish ingestion rates and sediment characteristics, and conservative risk and bioavailability considerations. For the bioaccumulation pathway, this entails back-calculating a sediment concentration from an ATL using biota-sediment accumulation factors. For assessing direct toxicity of sediment, conservative screening levels, or No Observed Effects Levels

(NOELs) can be used as a starting point. Bioaccumulation-based screening levels are only pertinent for those compounds that have been found to bioaccumulate in the Columbia Slough, based on the available fish tissue data. The lowest risk-based screening value for the sediment is established as the Tier 2 remedial action objective for Slough sediments (see Table 1). These screening criteria are designed to be conservative and reflect protective levels generically throughout the Slough. For particular segments of the Slough it may be possible to derive more representative risk-based concentrations, considering sediment characteristics specific to that section of the Slough, conducting bioassays that measure actual toxicity of the sediment, conducting bioaccumulation tests that measure contaminant concentrations in the tissue of organisms exposed to the sediment, or conducting more localized fish consumption surveys and fish tissue testing.

5.2 REMEDIAL ALTERNATIVES

There are three general categories of remedial alternatives for sediments. Contaminated sediments can be:

- Contained in place by capping,
- Removed, or
- Allowed to reach cleanup goals through natural mechanisms (referred to as natural recovery).

These options, along with phytoremediation, were considered in developing the remedial approach for Columbia Slough sediments. They are described in more detail in the following sections.

5.2.1 No Action Alternative

The no action option provides a baseline against which other sediment remedial alternatives can be compared. Under this option, the problem area remains unchanged, and nothing is done to mitigate public health and environmental risks.

5.2.2 Institutional Controls and Source Control

An institutional control is a legal or administrative tool implemented to reduce the potential for exposure to hazardous substances through contact with contaminated media. Institutional controls may include, but are not limited to, use restrictions, environmental monitoring requirements, and site access and security measures. Use and access restrictions may include measures such as identification and posting of health advisory signs. While fish consumption advisories and waterway use restriction can be important components of a sediment remedy,

these controls may not be very effective in eliminating or significantly reducing all exposures and are not effective in addressing ecological risks.

5.2.3 Monitored Natural Recovery/Enhanced Monitored Natural Recovery

Monitored natural recovery consists of leaving the contamination in place and allowing or enhancing ongoing natural processes to contain, destroy, or otherwise render the contaminants less likely to enter into the food chain or otherwise impact aquatic life. Enhanced natural recovery involves placing a uniform thin layer of clean sediment over the contaminated area or in berms or windrows, allowing natural sediment transport processes to distribute the clean sediment to the desired areas. As a result, natural recovery is accelerated through several mechanisms including increased dilution through mixing of clean sediment with underlying contaminated material.

Natural recovery tends to be more applicable to contamination that is present at low levels over widespread areas where more active measures are difficult to implement. It is important to understand the natural processes that will impact attenuation; *e.g.*, sediment transport and contaminant degradation. This remedial option will also require long-term monitoring and evaluation to confirm that contamination levels are attenuating as projected; and institutional controls are maintained, as warranted, to provide protection during this time.

5.2.4 In-situ Capping

In-situ capping refers to the in-water placement of a layer or cap of clean material over an area of contaminated sediment. Caps are generally constructed of granular material, such as clean sediment, sand, or gravel. The thickness of a cap is designed based on system hydrodynamics, contaminant concentrations, and contaminant mobility. A more complex cap design can include geotextile liners, and multiple layers. Depending on the contaminants and sediment environment, a cap reduces risk through the following functions:

- Physical isolation of the contaminated sediment from the aquatic environment;
- Stabilization/erosion protection of contaminated sediment, preventing resuspension and transport to other sites; and
- Chemical isolation/reduction of the movement of dissolved and colloidally transported contaminants.

Capping can encourage natural attenuation while preventing the spread of contaminants. A cap physically separates the contaminants from the overlying water. In this sheltered environment, microbial and abiotic (meaning non-biological) processes can act upon the contaminants. Should the cap ever be penetrated, these processes may have rendered the contaminant harmless. Caps can be designed to provide a habitat layer on the surface. The thickness of this layer should be sufficient to prevent benthic organisms from penetrating the cap, through a process called bioturbation. Typically this requires a minimum cap thickness of 10 centimeters (HSRC 1996).

Containing contaminated sediments is most effective and implementable when the contaminated area is relatively small, where the water depth is sufficient that the cap will not cause more frequent or damaging flooding, and where currents, tidal action, or future site activities are not likely to disturb the cap.

5.2.5 Dredging and Excavation

Dredging and excavation are means of removing contaminated sediments from a waterbody, either while it is submerged (dredging) or after water has been diverted or drained (excavation). Both methods necessitate transporting the sediment to a location for treatment and/or disposal. Treatment of water released from the sediment may also be required.

Removing the contaminated sediment is most appropriate for isolated areas of elevated contamination and is usually prohibitively expensive for widespread contamination. When evaluating dredging as a remedial option it is important to consider methods to control releases of contaminants during dredging and while transporting the material to an appropriate disposal location, and viable treatment (including dewatering)/disposal facilities.

Any material that is removed by excavation or dredging must be disposed of in a manner that is protective of human health and the environment either in an aquatic or upland environment. Disposal must also be in compliance with applicable local, state, and federal regulations. Disposal options may include in-water placement (confined aquatic disposal) and upland disposal in a permitted landfill. Because contaminant levels considered harmful in aquatic environments often meet protective levels for upland exposure scenarios, some dredged sediment may be used as fill for industrial sites or other upland areas. However, this may require a DEQ Solid Waste Landfill permit. Highly contaminated materials may have to be treated chemically or biologically, or incinerated prior to disposal.

5.2.6 Phytoremediation

Phytoremediation is a process that uses plants (*e.g.*, trees, grasses, aquatic plants) to remove, transfer, stabilize, and/or destroy contaminants in soil and sediment. Contaminants may either be organic or inorganic.

One of the main advantages of phytoremediation is that it is potentially less expensive than conventional remediation methods (Blac, 1995). Also, in upland systems, phytoremediation usually leaves topsoil in usable condition and reduces the amount of contaminated material to be landfilled or treated.

However, phytoremediation is not effective for strongly sorbed (*e.g.*, PCBs) and weakly sorbed contaminants. In addition, phytoremediation may require more time to achieve clean-up standards than other more expensive options. Moreover, vegetation that absorbs toxic heavy metals may also pose an unacceptable risk to wildlife that eat the plants. Evaluation of

phytoremediation in the slough was completed by analyzing contaminant levels in aquatic vegetation removed by MCDD to prevent clogging of pumps. This analysis indicated that extremely large volumes of plants would need to be removed to result in significant reductions in contaminant levels in sediment. Consequently, this remedial option is not included in the evaluation summarized in Section 6.

6. EVALUATION OF REMEDIAL ACTION OPTIONS

6.1 EVALUATION CRITERIA

OAR 340-122-0090(3) establishes five remedial action selection criteria: 1) effectiveness, 2) long-term reliability, 3) implementability, 4) implementation risk, and 5) reasonableness of cost. In addition, clean-up rules require an evaluation of how each alternative addresses hot spots of contamination.

The remedial criteria are described below:

- **Effectiveness in achieving protection.** The evaluation of this factor includes the following components:

  - Magnitude of the residual risk from untreated waste or treatment residuals, without considering risk reduction achieved through on-site management of exposure pathways (*e.g.*, engineering and institutional controls). The characteristics of the residuals are considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, propensity to bio-accumulate, and propensity to degrade.

  - Adequacy of any engineering and institutional controls necessary to manage residual risks.

  - The extent to which the remedial action restores or protects existing or reasonably likely future beneficial uses of water.

  - Adequacy of treatment technologies in meeting treatment objectives.

  - The time until remedial action objectives are achieved.

- **Long-term reliability.** The following components are considered when evaluating this factor, as appropriate:

  - The reliability of treatment technologies in meeting treatment objectives.

  - The reliability of engineering and institutional controls needed to manage residual risks, taking into consideration the characteristics of the hazardous substances being

managed, the ability to prevent migration and manage risk, and the effectiveness and enforceability over time of the controls.

- The nature and degree of uncertainties associated with any necessary long-term management (*e.g.*, operations, maintenance, monitoring).

- **Implementability.** This factor includes the following components:

  - Practical, technical, legal difficulties and unknowns associated with the construction and implementation of the technologies, engineering controls, and/or institutional controls, including the potential for scheduling delays.

  - The ability to monitor the effectiveness of the remedy.

  - Consistency with regulatory requirements, activities needed to coordinate with and obtain necessary approvals and permits from other governmental bodies.

  - Availability of necessary services, materials, equipment, and specialists, including the availability of adequate treatment and disposal services.

- **Implementation Risk.** This factor includes evaluation of the potential risks and the effectiveness and reliability of protective measures related to implementation of the remedial action, including the following receptors: the community, workers involved in implementing the remedial action, and the environment; and the time until the remedial action is complete.

- **Reasonableness of Cost.** This factor assesses the reasonableness of the capital, O&M, and periodic review costs for each remedial alternative; the net present value of the preceding; proportionality of costs to benefits to human health and the environment; and if a hot spot has been identified at this site, the degree to which the cost is proportionate to the benefits to human health and the environment created through treatment or removal of the hot spot.

  In general, the least expensive remedial action is preferred unless the additional cost of a more expensive action is justified by proportionately greater benefits under one or more of the other remedial factors. For sites with hot spots, the costs of remedial actions must be evaluated to determine the degree to which they are proportionate to the benefits created through restoration or protection of beneficial uses of water. A higher threshold will be used for evaluating the reasonableness of costs for treatment or removal of hot spots than for remediation of areas other than hot spots. The sensitivity and uncertainty of the costs are also considered.

6.2 UNIQUE COLUMBIA SLOUGH CONSIDERATIONS

The Columbia Slough and its contamination have unique characteristics that pose critical challenges in the selection of appropriate remediation options. These characteristics include:

- The Columbia Slough is a heavily managed system with human-engineered dikes to prevent flooding of the surrounding watershed, including the Portland Airport. Because of its flood control purpose, a certain amount of water-carrying capacity must be retained in order to safely and efficiently convey stormwater from the Upper and Middle Slough to the Lower Slough. The Upper and Middle Slough are typically fairly shallow, ranging from 1 to 3 feet deep. A typical sediment cap, commonly three or more feet thick, may not be a feasible option in the Middle and Upper Slough without losing flood-carrying capacity.

- The contamination in the Columbia Slough sediments is widespread at relatively low concentrations, generally reflecting impacts from pervasive and legacy sources in the surrounding urban environment. Active remedial measures, such as dredging and capping are unlikely to be feasibly applied to the entire Slough, but may be appropriate for isolated "source" areas.

- Because there are multiple wide-spread sources of contaminants to the Slough throughout the Slough watershed, source control is not straightforward and will likely be a complex long-term effort. Remedial actions for Slough sediment can only be effective to the extent that on-going contaminant inputs will not recontaminate sediment above the clean-up level achieved.

Because of these unique considerations, the evaluation presented in this document is somewhat different from a typical remedy evaluation conducted for a more defined site**.** This evaluation is meant to lay the foundation for a coordinated, watershed-based approach for addressing sediment contamination in the Columbia Slough and will consider a combination of several remedial elements in a framework for a long-term effort that incorporates consideration of watershed wide inputs, interagency coordination, and adaptive management techniques. It is important to remember however, that the ultimate goal of this effort is the same as a site-specific remedial action; that is, to reduce contaminant levels in the sediment throughout the Slough to concentrations protective of human health and the environment.

6.2.1 Source Control

The remedial options discussed in this document focus directly on existing contamination in sediment. It is recognized that for any of them to be effective, on-going sources of contamination will need to be controlled to the extent that they will not re-contaminate the sediment. With the exception of the no action alternative, all the options described in this section are assumed to include a source control component. Source control elements include

localized upland actions (*e.g.*, soil and groundwater cleanup, stormwater run-off treatment) at individual cleanup sites as well as actions implemented by the City to address widespread, pervasive sources of contamination (*e.g.*, stormwater controls, education programs). Watershed-based actions will be described generally in the City's Watershed Plan, expected to be completed November 2005. Current source control actions at individual cleanup sites are described in cleanup decision documents available through DEQ. The location and status of cleanup sites is provided on DEQ's web page for the Columbia Slough (http://www.deq.state.or.us/nwr/Columbia_Slough/cs.htm).

Additional source control actions or upland remedial actions will be selected consistent with this remedial approach and in accordance with DEQ regulations. It is anticipated that upland source control will be sufficient to prevent discharge or accumulation of contaminants in sediment at concentrations above Tier 2 levels.

6.2.2 Long-Term Monitoring and Institutional Controls

In addition to source control, all of the options considered in this section (with the exception of No Action) are assumed to include long-term monitoring and appropriate institutional controls as warranted to provide protection of human health. The City has developed a draft long-term monitoring plan for the Columbia Slough that includes sediment, water quality, and fish tissue sampling and analysis. In addition, the plan includes monitoring the effectiveness of stormwater controls. The plan includes reporting provisions and periodic evaluations of the data to determine if the remedial measures implemented are effective in reducing contaminant levels in the sediment.

6.3 EVALUATION AND COMPARATIVE ANALYSIS OF ALTERNATIVES

This section evaluates and compares each of the remedial action options identified in Section 5 using the factors described in Section 6.1.

6.3.1 Effectiveness

All alternatives, aside from No Action, can be effective in achieving protection. Removal of contaminated sediment is generally considered the most effective due to the relatively short time frame for achieving protective levels relative to natural recovery, and the lack of need for long-term management relative to capping options. Capping is considered more effective than natural recovery due to the shorter time frame required to achieve remedial action objectives.

6.3.2 Long-term Reliability

Alternatives that completely and permanently destroy the hazardous substances would have the highest level of long-term reliability since there are no requirements for long-term controls assuming protective levels are achieved. Removal has higher reliability than containment since

the exposure pathways of concern in the aquatic environment will no longer exist.

All the institutional and engineering control technologies have been used together or separately at other sites to reliably address contaminant issues. Therefore, the technologies that comprise capping and natural recovery alternatives are considered to be reliable long-term management approaches. The reliability of monitored natural recovery is judged to be somewhat lower than other alternatives (with the exception of the "No action" alternative) because natural recovery in freshwater systems in this region is relatively unproven and subject to a number of external variables (*e.g.*, temperature, oxidation-reduction potential, microbiological activity) that are difficult to control.

6.3.3 Implementability

All the alternatives are implementable at some locations in the Slough. Capping may be limited to the Lower Slough since the shallowness of the Upper and Middle Sloughs does not allow implementation of this alternative without losing flood carrying capacity. Because most of the properties along the Slough are privately owned, with infrastructures (industrial, commercial or residential) already in place, accessibility may be a major obstacle to bringing either large equipment or truckloads of capping material to the Slough. For the dredging alternative, finding a large enough parcel of land for staging, or for dewatering may be challenging. Obtaining accessibility may involve acquisition of permits (including Type III Land use reviews for environmental protection zones), easements and permission to rent land for staging, or other acquisition of necessary property interests.

6.3.4 Implementation Risk

Because of the nature of the no action alternative (which is used as a baseline for comparison), there are no impacts to workers, community, or the environment as a result of implementation. Similarly, the monitored natural recovery alternative does not involve any high risk due to implementation.

Capping also has low implementation risk. With in-situ capping, the contaminated sediments are left in place, which eliminates the potential for public or worker exposure. Contaminant redistribution is also minimized. With capping, there is a short-term loss of existing aquatic habitat which will eventually be re-populated if the correct habitat conditions are established. Capping material would need to meet cleanup levels. There will also be a short-term increase in turbidity downstream from the capped area. A minor risk may be associated with bringing in truckloads of capping material. The banks of the Slough are steep, and there is a minor physical risk to worker safety.

The dredging alternative is expected to create short-term resuspension and possibly redistribution of contaminated sediments. The fine sediments may remain suspended for an extended period of time and create a situation where there is increased surface area to volume ratio, allowing more partitioning of the contaminant into the water column and fish. The

environmental and community impacts may be mitigated by the control measures included with these alternatives. The implementation risk is therefore judged to be higher than that for the capping and monitored natural recovery alternatives.

Design, planning, permitting, acquisition of easements and construction of in-situ capping and sediment removal activities are expected to take 2 to 4 years. For the monitored natural recovery alternative, watershed improvement activities are already in place and ongoing.

6.3.5 Cost

For the purposes of this evaluation, the costs of the various alternatives are compared on a relative basis without specification of volume of sediment to be addressed.

Because a comparison of these options was completed for the Buffalo Slough, the estimated costs determined in that study have been used. Table 3 below shows the estimated costs for the remedial alternatives from the Buffalo Slough feasibility study.

Table 3: Estimated costs of remedial alternatives for Buffalo Slough (approx. 1 mile)

Remedial Alternative*	Estimated Cost** (in Million $)	Assumptions
No Action	0	No implementation activities
Monitored Natural Recovery	1.0	Assumed that institutional controls, including source control program in place, and implementation of the Watershed Plan. Stormwater treatment via commercially-available treatment devices.
Enhanced Monitored Natural Recovery (with thin-layer cap)	1.4	Same as monitored natural recovery with a 1-foot sediment cap.
In-Situ Capping	6.1	Placement of quarried sand and planting of in-stream wetland vegetation. Did not consider use of Columbia River sands (a less expensive option) due to uncertain availability and potential contaminant levels
Excavation / Dredging	10.3	Assumed that dredged material will be disposed of at a permitted landfill.

* Assumed that all remedial alternatives, except the no action alternative, have an implicit institutional control / source control program.

** Assumed a 20-year period and include only capital costs only. Effects of O&M costs are not included. Assumed 63,000 cubic yards of sediments are removed for the 1-mile stretch of Buffalo Slough.

6.3.6 Hot Spot consideration

There may be localized areas of the Slough sediment where contaminants are more elevated than other areas and may pose higher risk to aquatic life, wildlife and human health, as well as act as sources of contaminants to surrounding sediments. In these areas, active in-stream measures may have more viability than suggested in the above analysis. Response measures other than natural attenuation will be given priority for sediment in the Slough that exceeds risk-based **and** baseline concentrations. In cases, where this sediment also meets the criteria for hot spots as defined in OAR 340-122-0090, treatment or removal will be given priority in accordance with OAR Chapter 340 Division 122.

7. SELECTED REMEDIAL APPROACH

7.1 SELECTED APPROACH

The evaluation provided in Section 6 lays the foundation for utilizing a combination of approaches to address contaminated sediment in the Columbia Slough. The overall selected remedial approach for the Slough, pulling together the various techniques as appropriate, consists of the following components:

1. Source Control
2. Hot Spot Cleanup/Additional Remedial Measures
3. Natural Recovery and Appropriate Institutional Controls
4. Long-Term Monitoring and Evaluation.

In addition, the size and complexity of this project warrant breaking it up into more manageable units. Consequently, the selected approach includes evaluation focused on individual segments of the Columbia Slough that correspond to areas likely influenced by particular environmental or physical factors. The selected remedial approach components are described in Sections 7.2 – 7.6. The anticipated division of the Slough for evaluation is described in Section 7.7.

7.2 SOURCE CONTROL

As described in Section 3, there are both discrete and widespread, pervasive sources of contamination to the Columbia Slough. Needless to say, it is critical that on-going sources of contamination be eliminated in order to reduce contaminant levels in the Slough. The selected approach includes source control actions for both discrete and widespread sources.

7.2.1 Source Control at Identified Cleanup Sites

The first step in source control is to ensure that discrete sources of sediment contamination have been identified. This will be accomplished by reviewing available sediment data for the Slough, and identifying areas where contaminants are present at concentrations that exceed the "baseline" level. Where likely sources for these areas of elevated contamination have been identified and are in the DEQ cleanup program, investigation and necessary cleanup will continue according to the site-specific schedule established for the project. Where likely sources have not been identified, site discovery will be conducted to identify them. The site discovery tasks will include review of historical and current land use in the area immediately adjacent to

the affected sediment and all areas where surface water or stormwater runoff could be or could have been released to that location. Potential cleanup sites will be identified and prioritized for further action in DEQ's cleanup program.

Potential contribution to contamination in the Slough is evaluated for all DEQ cleanup sites in the Columbia Slough Watershed, typically as part of the remedial investigation at the individual facilities. This evaluation includes assessing movement of contaminants to the Slough via surface runoff, groundwater migration, input to storm sewer lines, and direct discharge. Remedial action is evaluated on a site-by-site basis at individual facilities to address any pathways found to provide a complete connection between the site and the Slough. The remedial action objective for upland source control is risk-based concentrations in Slough sediment and in the water column. It is important to note that cleanup of inputs to the Slough is based on reducing discharges/releases to levels that do not exceed protective, risk-based levels (i.e., Tier 2 levels) rather than baseline concentrations already present in the Slough. The only way to ultimately reduce baseline concentrations in the Slough is to reduce contaminant inputs to levels consistent with the ultimate risk-based cleanup goals.

In addition to controlling (i.e., minimizing, containing, eliminating) releases from identified contaminated sites, DEQ is also implementing preventative measures. DEQ has initiated and proposes to continue on a long-term basis a program to provide technical assistance to parties in the Columbia Slough watershed who treat, store, or manage hazardous substances. DEQ experts in hazardous waste management and pollution prevention are conducting site visits to willing parties in the watershed to provide guidance on proper management of hazardous substances and suggestions on how to reduce the use of chemicals that could adversely impact the environment.

7.2.2 Source Control for Widespread, Pervasive Sources

The City of Portland is implementing a wide range of actions aimed at addressing pervasive source contributions to the Columbia Slough. These include: installation of pollution reduction facilities at stormwater outlets to allow particulates to settle out prior to stormwater discharging to the Slough; education of residents in the watershed on ways they can reduce contaminant releases to the Slough; inspecting facilities discharging stormwater to the Slough and enforcing permit limits on those discharges; continued implementation of the illicit discharge elimination program; review of land development applications to ensure appropriate erosion controls are implemented; implementation of green streets actions to reduce amount of stormwater runoff; taking action on spill response and pollution complaints; disconnecting roof drains; revegetation and restoration of wetlands and other vegetative buffers; and providing technical assistance to industries about best management practices to reduce sources to and effectively manage stormwater. These activities will be broadly described in the City's Watershed Plan expected to be completed November 2005.

7.3 SEDIMENT CLEANUP/ADDITIONAL REMEDIAL MEASURES

In addition to implementing source control measures to prevent further release of contaminants to the Slough, property owners/operators are required to investigate and remediate contaminated sediment associated with their facility in accordance with Oregon environmental regulations. In many cases contaminant concentrations in Slough sediments in the areas affected by discharge from an individual upland facility will exceed baseline concentrations for the Slough. In these cases, responsible parties will not likely be required to remediate the contaminated sediment beyond the established baseline concentration. In many cases, the most straightforward method for addressing a limited area of sediment with elevated contaminant concentrations will be removing/dredging the most contaminated sediments and disposing them (with or without treatment) at an appropriate location. This also may be necessary if the contamination is determined to be a hot spot. Baseline levels are assumed to be the feasible and practical limit of cleanup of elevated areas of sediment contamination due to the presence of upstream contamination that could recontaminate sediments to surrounding, typically baseline, concentrations. Remedial actions for each individual site will be selected consistent with this remedial approach and in accordance with Oregon environmental cleanup regulations.

DEQ is not requiring upland parties that have contributed to contamination in the Slough to clean up impacted sediments beyond the Tier 1 baseline sediment concentrations. However, DEQ recognizes that these parties have contributed to the more widespread contamination and, consequently, a complete "No Further Action" determination would not be provided to upland parties unless sediment contamination in the vicinity of the site's discharge is cleaned up to risk-based concentrations (i.e., Tier 2). Note that risk-based concentrations may be developed using site-specific tests and factors pertinent to the particular portion of the Slough impacted, or, non-site specifically, by simply referencing the conservative screening levels (see Table 1) utilized in the Slough-wide evaluation. For those situations where cleanup to baseline concentrations does not result in achievement of protective risk-based concentrations, another option is provided to these parties that would allow them to receive a complete "No Further Action" finding. This option would allow parties that have cleaned up sediment associated with their site to baseline levels, to complete additional remedial measures at their site or in the Slough watershed in general geared toward achieving protectiveness in the Slough overall, as an alternative to reducing sediment concentrations at their facility to risk based levels. DEQ will work with the City, the MCDD, the Columbia Slough Watershed Council, and others to identify appropriate options that would reduce contaminant inputs to the Slough commensurate with a reasonable estimate of the mass of contaminants that were likely released to the Slough by a facility.

7.4 NATURAL RECOVERY AND INSTITUTIONAL CONTROLS

As localized areas of elevated sediment contamination are addressed and watershed-wide source control measures are implemented, it is anticipated that residual contaminant levels in Slough sediment will gradually decline as a result of natural processes. These processes include covering of contaminated sediments with clean material that continues to be washed into the system, biodegradation of organic compounds by native bacteria, erosion and dilution of

contaminants, and uptake of contaminants by aquatic plants. While these processes are slow, they represent the most practical, feasible mechanism for reducing residual, legacy contamination that is present throughout the Slough. While they exceed conservative screening levels, the baseline concentrations that will remain once the localized areas of elevated sediment contamination have been addressed are generally low. This wide-spread, low-level contamination is the typical scenario for taking advantage of natural recovery mechanisms to achieve ultimate cleanup goals. It is critical, however, that adequate monitoring be conducted to ensure that source control and natural recovery are successfully reducing contaminant levels in the sediment over the long term. Fish advisories and associated public education efforts will continue until data indicate protective tissue levels have been attained.

7.5 LONG-TERM MONITORING AND EVALUATION

The City has monitored various parameters in the Columbia Slough for several years in support of Water Quality discharge limits, total maximum daily load (TMDL) evaluations, and environmental investigations. The selected remedial approach for Columbia Slough sediments requires formalizing and expanding the existing monitoring to ensure that improvements in sediment quality are achieved. A long-term monitoring plan for the Slough has been drafted by the City and is currently undergoing revision based on DEQ input. It includes the following components:

a) Ambient water quality
b) Stormwater quality
c) Sediment quality
d) Fish tissue levels, and
e) Bioaccumulation assessment.

In addition, monitoring will include data collection to assess the effectiveness of Pollution Reduction Facilities (PRFs) and Best Management Practices (BMPs) implemented for stormwater quality improvement and surveys to assess potential contaminant receptors, such as those who fish in the Slough.

These data will be collected on a routine basis established in the monitoring plan and will include periodic evaluation to assess contaminant trends. This evaluation will be used to determine the effectiveness of source control and cleanup actions, identify new or undiscovered sources of contamination, and determine whether fish advisories continue to be warranted.

Data may also be collected to refine the screening level risk assessment for the Slough and modify the Tier 2 screening levels as appropriate. This might include bioassays to support site specific toxicity-based cleanup levels or bioaccumulation studies to support site-specific bioaccumulation cleanup levels.

Data summary and evaluation reports will include discussion of actions that appear to be successfully reducing contaminant levels in Slough sediment and areas where additional

measures may be required. For example, the data may indicate that more active sediment cleanup measures may be warranted in certain portions of the Slough.

7.6 ADDITIONAL CONSIDERATIONS

Additional activities not specifically related to the remedial action for the Slough should result in reductions in contaminant levels in the sediment. One such activity is the harvesting of macrophytes and algae to improve flow conditions and prevent "clogging" of pumps. This will result in removal of a small amount of contaminants that are taken up by the aquatic plants. Another activity is periodic dredging that is conducted for flood control purposes.

7.7 EVALUATION APPROACH

Because the Columbia Slough and its associated watershed encompasses such a large area, the selected remedial approach includes a process for focusing evaluation efforts on particular sections of the Slough that can be segregated primarily based on flow dynamics. Under this approach, a determination of the adequacy of efforts to identify new sources of contamination and ultimately whether protective contaminant concentrations in sediment have been achieved would be made on a segment by segment basis.

The following segments are proposed for individual evaluation:

a) Wapato Wetlands
b) Peninsula Drainage Canal
c) Buffalo Slough
d) Whitaker Slough
e) Lower Slough
f) Middle Slough
g) Upper Slough.

DEQ has already issued a No Further Action determination for the Wapato Wetlands where it has been determined that the contaminants present in this portion of the Slough are not bioavailable and consequently do not pose an unacceptable risk to receptors.

DEQ has also provided a partial No Further Action determination for the Peninsula Drainage Canal concluding that further efforts to identify sources of contamination to this section of the Slough are not warranted based on levels of contamination that are consistent with baseline concentrations established for the Slough overall. The NFA letter indicates, however, that continued monitoring will be required to ensure that baseline concentrations decline over time or, if they do not, support evaluation of additional remedial measures.

The City has conducted additional monitoring and prepared a feasibility study for the Buffalo Slough. DEQ has considered this feasibility study in completing the feasibility study for the Columbia Slough overall. Current efforts in the Buffalo Slough are focused on ensuring that all

discrete sources of contamination have been identified and continuing with implementation of general source control measures.

For the remaining sections of the Columbia Slough, available data are being evaluated to identify localized areas of elevated contamination and likely associated sources, complete investigations and clean up identified sources, implement source control measures, and conduct long-term monitoring. It is anticipated that for each segment there will be two primary phases of remediation:

a. Source identification and source control implementation – During this phase, discrete sources of contamination will be identified and the City will implement appropriate source control measures at municipal stormwater discharge locations. DEQ will issue a preliminary NFA determination to the City once these steps have been completed.

b. Hot spot clean up and long-term monitoring – During this phase, responsible parties will complete a risk assessment, implement site-specific upland source control activities, treat or remove hot spots, and clean up sediment contamination associated with their facility to the extent feasible (*i.e.*, may only achieve baseline concentrations). The upland party will implement necessary upland cleanup and source control measures and monitor the long-term effectiveness of source control actions (*e.g.*, stormwater, groundwater, sediments). The City will monitor sediment, biota, and water quality in the Slough to assess the effectiveness of the source control and cleanup actions. DEQ will issue a final NFA determination for the segment under evaluation to the City once risk-based concentrations are achieved.

8. PUBLIC NOTICE AND COMMENT

DEQ's notice of the proposed remedial approach was published on April 1, 2005 in the Secretary of State's Bulletin and The Oregonian. Copies of the Staff Report for Proposed Remedial Approach, and other documents that make up the Administrative Record were made available for public review at DEQ's Northwest Region offices in Portland, the main branch of the Portland Public Library in downtown Portland, and the Parkrose High School Library located at 12003 NE Shaver St. in the Columbia Slough watershed. The public comment period began April 1 and ended May 16, 2005. An overview of the proposal was provided at the Columbia Slough Watershed Council meeting held April 25, 2005. DEQ's response to comments are summarized in Section 9.

9. CONSIDERATION OF PUBLIC COMMENTS

9.1 Columbia Slough Watershed Council – Oral Comments

Several questions came up during the DEQ presentation at the Columbia Slough Watershed Council meeting. One person asked, if evaluation of the sediment data collected as part of long-term monitoring resulted in a reduction in the baseline level, would parties that had completed cleanup to baseline be required to conduct additional remediation. DEQ responded that this would only occur if the area in question showed some unusual contaminant trend that suggested a continuing source of contamination or ineffective natural attenuation. Another person asked if remedies that involved capping would interfere with MCDD maintenance dredging activities. DEQ and MCDD responded that there was close coordination between MCDD and DEQ on remedial activities in the Slough and that potential future dredging would be considered as part of the feasibility study for individual site remedial actions. In some cases, capping may be implemented in conjunction with a limited sediment removal action to ensure that the cap would not exceed the elevation required in the Slough for effective flood management. Another question was raised about disposal options for material dredged from the Slough. DEQ indicated that a variety of options are possible depending on the level of contamination present in the material dredged. DEQ noted that, in many cases, contaminant levels that pose a potentially unacceptable risk when present in a water body (due to the potential for exposure to sensitive aquatic organisms and bioaccumulation concerns), do not pose an unacceptable risk for an upland environment. In these cases, dredged material can be placed in upland areas that will not come into contact with waterbodies, without any additional restrictions. DEQ is working with MCDD to allow use of such material for landward side dike stabilization where appropriate.

9.2 Stoel Rives – Mark Morford

DEQ received the following written comments from Mark Morford, an attorney with Stoel Rives, LLP:

1. Mr. Morford comments that the proposed approach does not address a particular site, does not appear to be based on a site specific remedial investigation and risk assessment, and selects remedial action for sites not yet identified.

   DEQ makes several clarifications in response to this comment. The proposed approach does in fact address a particular site, that site being contaminated sediment throughout the Columbia Slough. As indicated in Section 6.2 of this

proposal, this site is unique, in that the contaminated sediment is spread throughout a large area overlapping many more localized cleanup sites. A detailed risk assessment could not be conducted on contamination spread over such a large area without expending huge amounts of resources and time. Consequently, it was decided to select a cleanup approach based on a screening level risk assessment. While particularly suitable to this site, this approach is also an option for specific contaminated sites where parties decide to implement remedial measures based on conservative screening levels rather than complete a more detailed risk assessment. The approach selected for the Columbia Slough does not determine or limit remedial options for parties conducting more discrete investigations and cleanup actions within the Slough. Remedial actions will be selected by DEQ on a site-by-site basis consistent with the selected remedial approach and in accordance with DEQ's cleanup regulations. The selected Slough sediment remedial appraoch identifies site cleanup and source control actions as critical to achieving the ultimate goal of reducing contaminant levels in the Slough sediments throughout the watershed. To further clarify this point, DEQ recognizes that parties conducting risk assessment of contamination associated with their facilities may complete more detailed site-specific evaluations of the risk posed by contaminated sediment associated with their facility, accounting for specific sediment conditions, flow conditions, and exposure factors. The result of such risk assessments may indicate that contaminant levels present do not present an unacceptable risk even though they exceed baseline concentrations developed for the Slough or the conservative screening levels used in the screening level risk assessment. On the other hand, parties may find it more efficient to conduct a limited remedial action for sediment associated with their facility using the baseline concentrations and conservative risk values generated for the larger Slough area without completing the more detailed risk assessment. Neither of these options is precluded by the selected approach for the Columbia Slough.

2. Mr. Morford comments that the screening level risk assessment referenced in the proposal cannot be used as a basis for requiring remedial action at individual sites located in the Columbia Slough watershed.

As indicated in the response to Mr. Morford's first comment, DEQ is not precluding individual sites from conducting risk assessments specific to their facilities. The selected approach for sediment Slough-wide is necessarily based on a limited data set relative to the size of the area covered. The approach provides a means for identifying sites where specific sources of contamination to the Slough may be located and may pose unacceptable risk, but leaves the final determination of risk to the site-specific evaluation. This is a standard element of DEQ's site discovery process.

3. Finally, Mr. Morford comments that the use of the term "hot spots" in the proposal is not consistent with the definition provided in Oregon statute and rule.

   DEQ agrees that the term "hot spot" may have been used too loosely in the proposal. In many cases, DEQ used this term to reference an area of the sediment where contaminant levels are elevated above the levels observed throughout the Slough in general and therefore appear indicative of a nearby release. These areas of elevated contamination will be used by DEQ to identify potential nearby sources of contamination and, where parties are not inclined to conduct detailed site-specific risk assessments, may end up defining an area where active remedial measures will be implemented. DEQ has added some clarifying language to this effect through the description of the selected approach and, where appropriate, has replaced the term "hot spot" which has specific criteria associated with it under Oregon law, with the words "area of elevated sediment contamination."

9.3 Associated Oregon Industries

DEQ received the following written comments from Associated Oregon Industries (AOI):

1. AOI comments that the process for obtaining a complete NFA when cleaning up to baseline concentrations is not adequately defined and thus reduces the incentive for parties to undertake voluntary cleanups and creates liability uncertainty for businesses along the Slough.

   DEQ agrees that the process for obtaining a complete NFA for parties cleaning up to baseline concentrations that exceed protective risk-based levels is not well-defined. The "alternative remedial measures" approach is a unique option, yet to be developed in any level of detail. DEQ included it in the proposed approach as it seems to have particular value for the unique conditions presented by the Columbia Slough sediment site. The process for identifying viable alternative actions and determining value commensurate with likely site contribution to contamination in Slough sediments will be completed site-specifically and, over time, we are hopeful that a workable framework can be developed.

   DEQ does not agree that the partial NFA provided for sites where cleanup does not achieve risk-based concentrations will prove to be a disincentive to parties working voluntarily with DEQ. The tradeoffs between voluntary and enforced action are not altered by the ultimate outcome of the action that is required since that outcome is the same under either scenario. It should be recognized that the partial NFA provided under the scenario where cleanup to baseline is completed but baseline levels exceed protective risk-based concentrations will reflect a significant conclusion by DEQ and the likelihood that additional action will be required to address residual sediment contamination will be low. As indicated in the selected approach, the relatively low contaminant levels represented by the baseline concentrations are unlikely to warrant

active remedial measures and are much more suitable to cleanup via natural recovery mechanisms. The costs associated with natural recovery will be borne by the City of Portland as part of the long-term monitoring and evaluation it has committed to perform, as described in their draft monitoring plan, and so should not present a financial liability to individual parties.

2. AOI comments that a more rigorous assessment of the nature and extent of sediment contamination and associated potential risks should be completed to allow for prioritization of sediments warranting more immediate cleanup.

   DEQ agrees that the data upon which the proposed approach is based are limited considering the size of the site. However, the size of the site makes more rigorous evaluation of questionable value relative to the expenditures that would be required. DEQ does intend to utilize existing data and data that will be collected as part of the long-term monitoring plan for the Slough to prioritize areas where sediment cleanup is warranted. This was initially done as part of the Screening Level Risk Assessment, in which sediment samples were prioritized based on risks associated with the contaminant levels detected, and will be revised and updated considering the baseline levels developed and additional data that will be collected in 2005/2006. In addition, data collected as part of long-term monitoring may be used to revise the risk-based screening levels currently identified, making them more reflective of specific conditions within the Columbia Slough. While our understanding of risk and priorities will necessarily change over time as part of the adaptive management approach proposed, this will not alter the overall framework presented in the selected remedial approach; *i.e.*, source control, active cleanup of elevated areas of sediment contamination, natural recovery, and long-term monitoring.

3. AOI comments that sources for indicated contamination and associated potential risk are not adequately referenced.

   DEQ has corrected the Administrative Record Index to include the Feasibility Study completed by DEQ and the City of Portland Bureau of Environmental Services which was inadvertently left out of the original staff report. The Feasibility Study is available on DEQ's web page (**http://www.deq.state.or.us/nwr/Columbia_Slough/cs.htm**) and provides pertinent references for all the data and evaluations utilized in this study.

4. AOI comments that Table 1, which lists the sites currently identified in DEQ's cleanup site database, are inappropriately referenced in the Feasibility Study as sites that are current or historical sources of contamination to sediment in the Slough. AOI further comments that it should be clarified that these are not the only potential sources of contaminants in the Slough.

DEQ agrees that the reference to the sites in Table 1 should indicate that the sites are potential current or historical sources. DEQ believes that the selected approach is clear that additional yet to be identified sources may also exist. That is why an important element of the approach is continued site discovery as described in Section 7.2.1.

5. AOI comments that a conceptual site model should be included in the report or appropriately referenced.

   A conceptual site model is provided in the Feasibility Study, Figure 2-1. A reference to this figure has been added to Section 3.2.2.

6. AOI comments that contaminants of concern should be reviewed and prioritized and the references for estimating risk posed by particular contaminants should be provided.

   In effect the contaminants of concern have been prioritized based on level of exceedance of the risk-based screening levels and whether they were detected in fish tissue. Appendix B of the Feasibility Study includes references for the calculations that were made to develop the risk-based screening levels for the Slough. As indicated, this table is draft and is currently undergoing review by DEQ toxicologists. However, the specific screening levels developed are not expected to alter the proposed remedial approach for the Slough.

7. AOI questions whether the identification of ecological contaminants of concern adequately considered natural background levels for inorganic chemicals.

   As indicated in Appendix B of the Feasibility Study, background concentrations were identified as the appropriate screening level for most of the metals identified as potential contaminants of concern in the Slough. Default background concentrations established for freshwater systems were utilized in this evaluation.

8. AOI specifically requests references for the biota sediment accumulation factors (BSAFs) and risk-based screening levels identified in the text.

   The table of BSAFs and other factors and equations used to generate the risk-based screening levels are documented in Appendix B of the Feasibility Study.

9. AOI comments that the impacts of sediment migration and redistribution on sediment remedial activities are not adequately discussed and, in particular, points out that a study conducted by Portland State University and the City of Portland found that tidal flushing significantly impacts sediment movement in the Lower Slough.

DEQ agrees that hydraulic factors will influence sediment movement in the Slough and, in fact, is relying on this to some extent to achieve reductions in contaminant concentrations as a component of natural recovery. These factors will be considered in evaluating contaminant distribution patterns over time as well as in site specific evaluations of sediment contamination associated with particular source areas.

10. AOI comments that metrics should be developed to evaluate progress in source control.

DEQ agrees that source control is a critical element of the remedial approach for the Slough. Appropriate metrics for evaluating the adequacy of source control measures will be developed as part of the long-term monitoring plan. DEQ anticipates making the draft plan as well as the periodic reports summarizing data collected and associated evaluations, available for public comment and encourages AOI to provide input on these documents.

11. AOI comments that No Further Action determinations should be provided to any party that can demonstrate that sediment contamination does not pose an unacceptable risk or is below baseline concentrations.

DEQ has added some clarifying language to Section 7.3 that should address the concern raised by this comment. DEQ did not intend that parties responsible for sediment contamination in the Slough would have to reduce concentrations to the conservative screening levels established for the Slough in order to document no unacceptable risk. As indicated in comment responses above, parties can conduct site-specific risk assessments for the particular area of the Slough impacted by their site and use this evaluation in determining a risk-based cleanup. A complete NFA determination will be provided to those parties that can demonstrate sediment concentrations associated with the release from their site are below levels that reflect an unacceptable risk assuming all other risk issues for the site have been adequately addressed. However, in those cases where the risk-based concentration (site-specific or generic Slough) is below the baseline concentration and the responsibility party remediates sediment to the baseline levels, the NFA determination will indicate that some continued responsibility may remain for the contribution the site release made to the baseline levels.

12. AOI comments that the option for parties to conduct “additional remedial measures” in lieu of cleanup to risk-based concentrations when those concentrations fall below baseline levels is not adequately developed and likely more complex than DEQ implies.

DEQ agrees that this option is not well developed at this point. DEQ recognizes that estimates of historical contribution to contamination in the Slough will be impossible to accurately quantify in most cases. Correspondingly, the value of alternative

measures in terms of reducing contaminant input to the Slough will similarly be difficult to quantify. DEQ accepts that there is a high level of uncertainty associated with this option but has concluded that the promotion of actions designed to improve environmental conditions in the Slough justifies taking the risk that exact balances will not be achieved. Alternative remedial options will be developed on a site-specific basis and will be subject to public review and comment through the remedial action process. We encourage AOI to provide input on any such proposals as they are developed.

13. AOI comments that portions of Table 1 appear to include some internal DEQ communications.

    DEQ has deleted the column in this table that addresses Eyes on the Slough monitoring, but has left the status column in tact as it provides information on site status that may be of interest to the public.

9.4 Maul Foster Alongi – Precision Equipment Site

DEQ received the following written comments from Maul Foster Alongi, Inc. (MFA) related to the documentation associated with the Precision Equipment Site that is provided in the Table 1 Slough site summary. Note that these comments pertain to specific facts related to a particular site in the Slough and do not impact the selected remedial approach for the Slough.

1. MFA comments that PCBs were not detected above Preliminary Remediation Goals (PRGs) on the Precision property and so should not be identified as a contaminant associated with the site.

   PRGs designed to be protective for upland exposures may not be protective of impacts in an aquatic habitat. Consequently, the fact that PCBs were detected in the soil of the Precision Site and were found at elevated concentrations in sediment samples collected from the Slough adjacent to the site are sufficient to identify PCBs as a potential contaminant of concern.

2. MFA comments that the statement indicating that contamination to the Slough via the storm line is undetermined suggests that this is an evaluation that still needs to be completed by Precision.

   DEQ disagrees. The statement simply reflects the fact that it is difficult to determine sources of contamination to the storm line, a fact that Precision agrees with. No implication for further action by Precision in relation to answering this question is implied.

3. MFA comments that the statement that a Tier 1 ecological risk assessment must be completed for area 3 is inaccurate.

DEQ has requested a Tier 1 ecological risk assessment for area 3 to assess risk to ecological receptors in this area. It is unrelated to evaluating impacts to the Slough.

4. MFA comments that the statement indicating that sediment sampling in the Slough will be required is inaccurate.

   Historic air photos clearly show a surface water flow channel that discharges to the Slough in the northwest and northeast corners of the Precision and adjacent Wastech properties. Concentrations of onsite soil contaminants, likely surface water discharge, and elevated concentrations of these contaminants in the Slough support the need for sampling sediment in the Slough as part of the remedial investigation for this site.

5. MFA comments that the presence of a historic sludge pond beneath the Precision site property and surrounding properties has not been confirmed.

   DEQ agrees that further study of air photos suggests that the varying size surface water bodies that appear in this area prior to the 1950s may be natural lake features rather than sludge ponds. DEQ will correct this characterization in the next update of the site status report.

10. DOCUMENTATION OF SIGNIFICANT CHANGES

As described in Section 9, the Department has made a number of changes in the text of the selected remedial action from what was included in the staff report proposal (March 2005). These changes were made in response to comments received during the public review period. The most significant changes are summarized below:

1. The text has been clarified to indicate the selected remedial approach applies to Slough sediment.

2. The discussion of remedial actions at upland facilities has been clarified to indicate that these actions will be selected in accordance with Oregon Environmental cleanup laws on a site-by-site basis.

3. The use of the term “hot spot” has been limited to avoid confusion with the specific definition of this term provided in Oregon cleanup regulations.

11. STATUTORY DETERMINATIONS

The selected remedial approach for the Columbia Slough sediments provides a framework for future remedial actions that should be protective and reflect the best balance of trade-offs considering treatment of hot spots, effectiveness, long-term reliability, implementability, implementation risk, and reasonableness of cost. Long-term monitoring will provide the basis for DEQ's final determination of whether the approach satisfies these statutory requirements and whether additional cleanup action is necessary. The selected approach therefore is consistent with the requirements of ORS 465.314 and OAR 340-122-0090.

12. SIGNATURE

_____ _____

Dick Pedersen, Administrator Date
Northwest Region, Department of Environmental Quality

APPENDIX A

ADMINISTRATIVE RECORD INDEX
COLUMBIA SLOUGH SEDIMENT
Portland, Oregon

The Administrative Record consists of the documents on which the recommended remedial approach for the site is based. The primary documents used in evaluating alternatives for the Columbia Slough Sediment site are listed below. Additional background and supporting information can be found in the Columbia Slough project file located at DEQ Northwest Region Office, 2020 SW 4th Ave., Portland, Oregon.

SITE-SPECIFIC DOCUMENTS

Order on Consent, DEQ No. ECSR-NWR-93-09 between DEQ and City of Portland, dated October 7, 1993.

Adolfson Associates, Inc 1996. Technical Memorandum on the Results of the 1995 Fish Consumption and Recreational Use Surveys, from Jean Ochsner to Chee Choy, City of Portland, April 19, 1996.

Ecology and Environment, Inc. 1998. "Final Sediment Characterization Report and Risk Assessment, Marx-Whitaker Subbasin of Whitaker Slough, Early-Action Remedial Activities, Columbia Slough Sediment Project," prepared for Portland Bureau of Environmental Services, August 1998.

Oregon DEQ 2002. Columbia Slough – Baseline Concentrations, Documentation of Methodology, November 21, 2002.

Oregon DEQ 2005. Feasibility Study – Columbia Slough Sediments, Remedial Action Approach, March 17, 2005

Parametrix, Inc. 1995. Columbia Slough Sediment Remedial Investigations/Feasibility Study Screening-Level Risk Assessment.

Parmetrix, Inc. 1997 Endangerment Assessment for Buffalo Slough.

Portland Bureau of Environmental Services 1998. Fish Consumption and Human Health Carcinogenic Risks Posed by Contaminated Sediments in the Peninsula Drainage Canal, September 1998.

STATE OF OREGON

Oregon's Environmental Cleanup Laws, Oregon Revised Statutes 465.200-.900, as amended by the Oregon Legislature in 1995.

Oregon's Hazardous Substance Remedial Action Rules, Oregon Administrative Rules, Chapter 340, Division 122, adopted by the Environmental Quality Commission in 1997.

GUIDANCE AND TECHNICAL INFORMATION

DEQ. Guidance for Conducting Feasibility Studies. July 1998.

DEQ. Guidance for Identification of Hot Spots. April 1998.

USEPA. Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. OSWER Directive 9355.3-01. October 1988.